Skip the "skip zone": we created it and we can eliminate it

by Lt. Col. David M. Fiedler

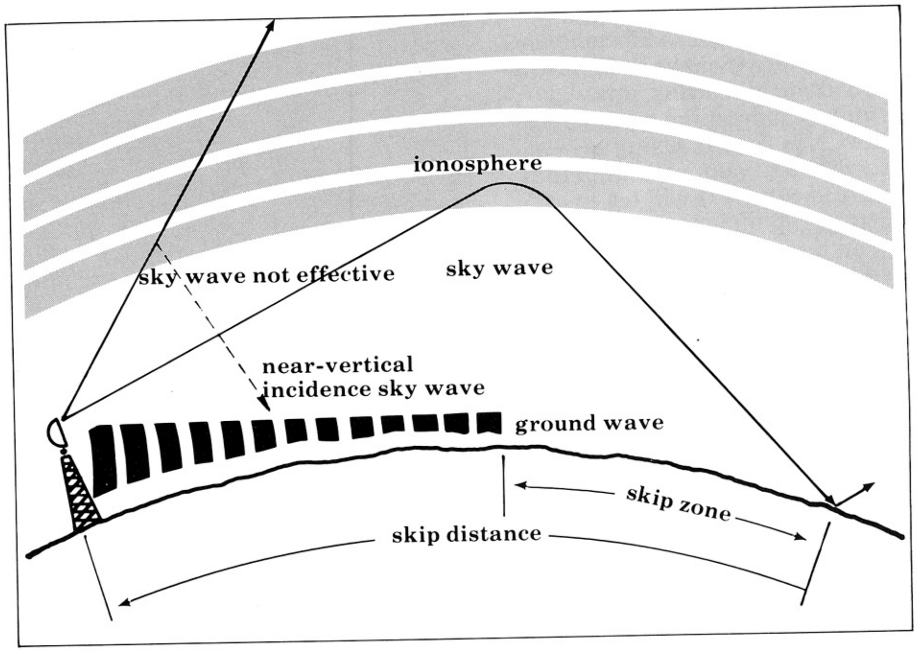

Figure 1. This illustration from* FM 24-18 *and other publications shows the incorrect concept of a skip zone. If such a skip zone exists when not desired, the communicator has improperly selected the antenna or antenna height.

Current doctrine is wrong. There* can *be a skip zone if the communicator selects an antenna with too low a radiation angle,* but there is no skip zone unless you, the communicator, create it! . . . *We must banish forever the term "skip zone" and the thinking that created it.

For many years, Army publications dealing with high frequency (HF) radio communications (i.e. *FM 24-18, FM 24-1, FM 11-65, TM 11-666,* and others) have used the diagram shown in Figure 1. These publications explain how HF radio signals (2-30 MHz) are propagated either as groundwaves or skywaves. They correctly define a groundwave as energy radiating along the surface of the earth until it reaches a point (10 to 70 miles distant) where the energy level becomes too low to be of use for communications. And they define a skywave as energy radiated at an upward angle from the antenna and reflected back to the earth's surface by the ionosphere, adding, however, that this reflection should be expected at a point no less than 100 miles from the antenna. Thus, they claim there is a gap, or "skip zone," of 30 to 90 miles (beginning where the groundwave becomes too weak for communication and ending where the skywave returns to earth) in which HF radio communications are ineffective. To quote *FM 24-18:* "There is an area called the skip zone in which no useable signal can be received from a given transmitter operating at a given frequency. This area is bounded by the outer edge of useable groundwave propagation and the point nearest the antenna at which the skywave returns to earth." This doctrine is wrong. There *can* be a skip zone if the communicator selects an antenna with too low a radiation angle, *but there is no skip zone unless you, the communicator, create it!*

After many years of urging by myself and others, the December 1984 issue of *FM 24-18* finally included an appendix (Appendix N) on near vertical incidence skywave (NVIS) HF propagation. This appendix clearly shows how, by adjusting antenna heights and transmitter frequencies, an operator can obtain high angle radiation and eliminate skip zones. Apparently, however, the subject area experts of the Signal School did not grasp the significance of Appendix N, since they allowed Figure 1 (which is a reproduction of Figure 2-15 in the manual), an illustration of a "skip zone," to remain in the same manual untouched. Because the ranges covered by the so-called skip zone are of particular significance to the Army for many tactical reasons, it is important to understand what Appendix N is saying. Using a slightly different approach than that used in Appendix N, I will try to demonstrate again how the "skip zone" can be avoided.

First, however, we need to take a quick look at the accompanying illustrations. Figure 2 shows the relationship between the angle of radiation and the distance covered, assuming an average height of the ionosphere. It shows, for example, that if a station wishes to continuously cover a distance up to 200 miles (approximately the depth and width of an Army corps), it needs to radiate its signal at all angles between 52 and 87 degrees toward the zenith (i.e. in a vertical direction). Figure 3 shows that a horizontal dipole antenna .25 wavelengths above ground will direct most of its energy between these angles. Figure 4 shows that a vertical antenna .5 wavelengths above ground will do likewise with almost equal efficiency. Thus, provided that the operating frequency does not exceed the maximum useable frequency (MUF), either of these simple, commonly available configurations will do the job of directing energy nearly vertically so that it will be scattered and reflected downward by the ionosphere.

MUFs can easily be determined using ionospheric sounding or propagation prediction tables. If these are not available, use the common rule of thumb (2-4 MHz nighttime, 4-8 MHz daytime). The best operating frequency is usually about 20-25 percent below the MUF. Figure 5 is a compiliation of all angles of radiation vs. antenna height in wavelengths for horizontal (black curves) or vertical (white curves) antennas. Using this figure, we see the same results as before. A horizontal dipole, .1-.25 wavelengths above ground, radiating energy at all angles between 51 and

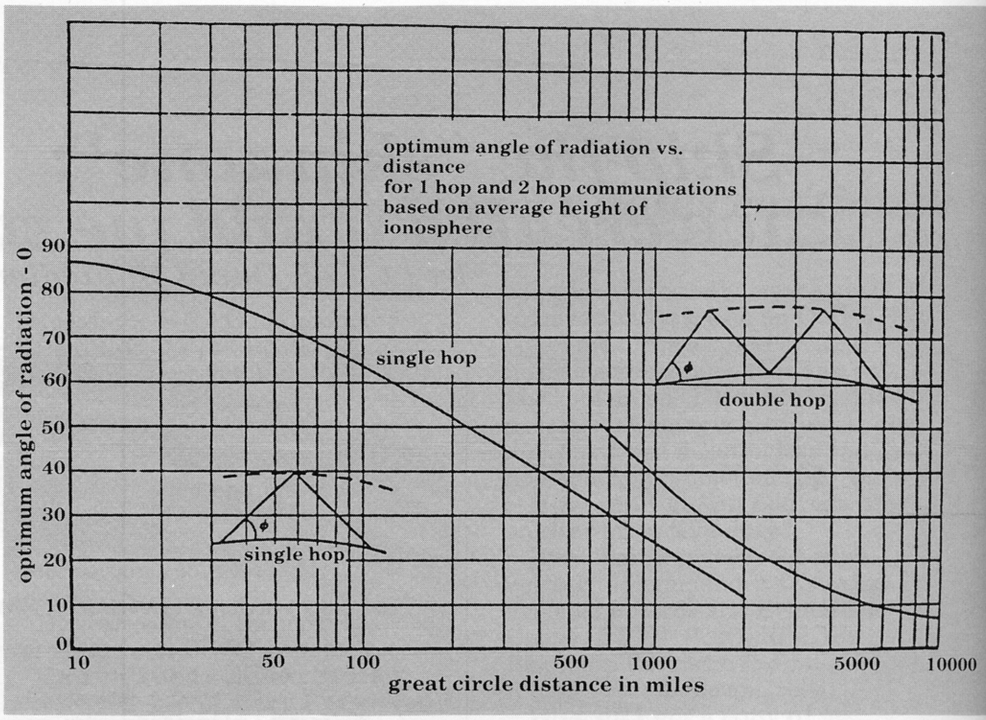

Figure 2. Radiation angle vs. range (from The Rules of the Antenna Game*).*

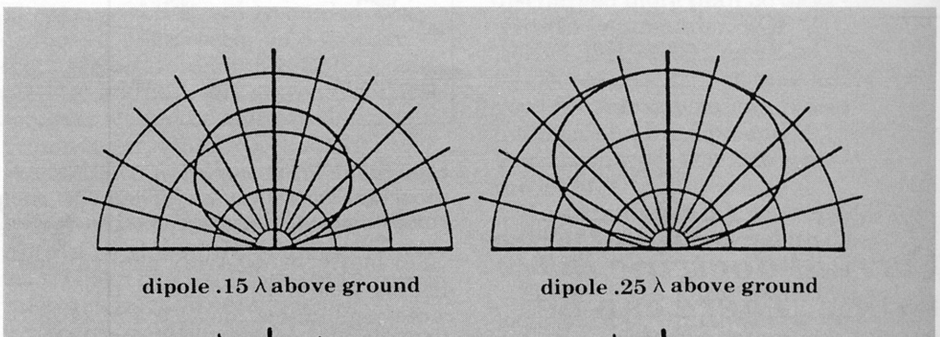

Figure 3. Horizontal dipole radiation patterns at various heights (in wavelengths) above the ground (from Air Force Comm. Pam. 100-16*).*

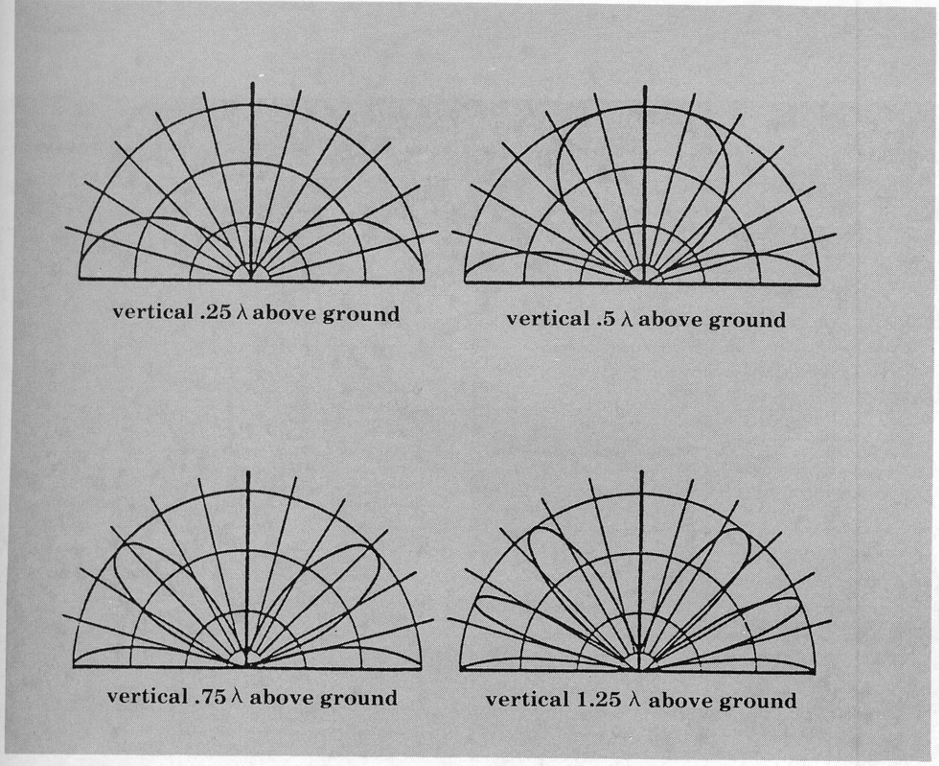

***Figure 4. Vertical dipole radiation patterns at various heights (in wavelengths) above the ground (from Air Force* Comm. Pam. 100-16).**

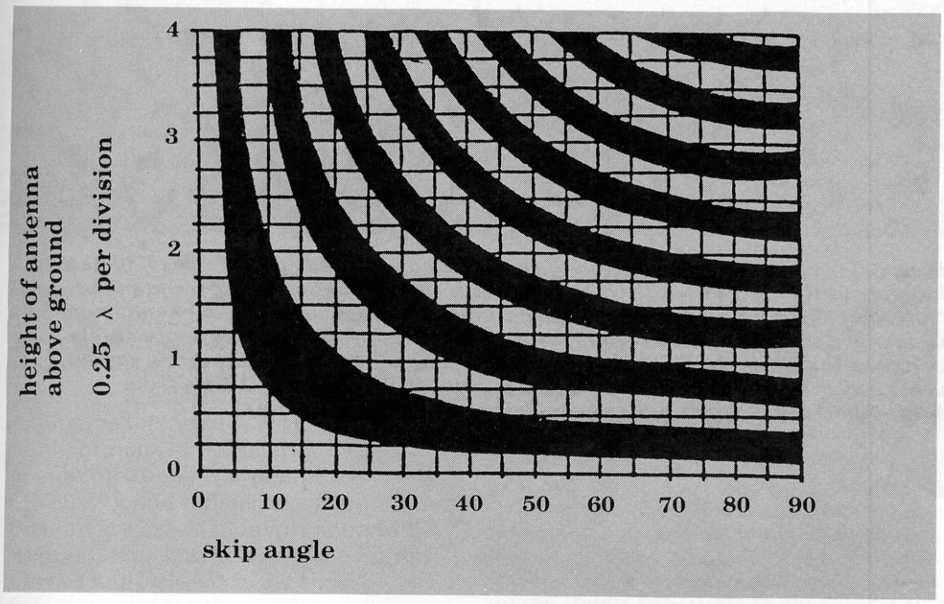

***Figure 5. Radiation angle vs. antenna height above ground. Select the antenna height for range of radiation angles desired (from* The Rules of the Antenna Game).**

87 degrees, falls directly within the first black curve. Similarly, a vertical antenna, .5 wavelengths above the ground, radiating energy at all angles between 50 and 90 degrees, falls directly within the first white curve.

Wavelength (λ) can be calcuated using the equation:

$$\text{wavelength}(\lambda) \text{ in meters} = \frac{300}{\text{frequency (in MHz)}}$$

For example, if our operating frequency were 5 MHz, the wavelength would be 300/5=60 meters. For a horizontal dipole antenna to radiate energy at the necessary angles, it would have to be 6 (.1λ) to 15 (.25λ) meters above the ground. Similarly, a vertical dipole would have to be 30 meters (.5λ) above the ground for the same result at this operating frequency.

Knowing the above information, operators can use the following steps in order to provide continuous, skip zone free HF radio communications for military operations.

1. From the operations order or other directive, determine the ranges to all stations in the net. Stations within 500 miles (well within a division or corps area) can be easily reached using simple dipole antennas—provided a propagating frequency is available.

2. From Figure 2, determine the range of angles required to transmit energy over the distance required.

3. From ionospheric sounders, propagation tables, or other predictions, determine the range of frequencies required to support propagation throughout the day. (The frequency will change depending on the time of day, thus requiring frequency shifts and retuning of radios and antennas for 24-hour operation. Typical changes are shown in Figure 6.)

4. From the authorized frequency list provided to your unit, select operating frequencies which fall within the range determined in Step 3. (If no authorized frequencies fall within this range, you will not communicate past groundwave range.)

5. After selecting the operating frequency, select the antenna type desired (vertical dipole, horizontal dipole, etc.).

6. Calculate the required antenna height in wavelengths.

$$\text{wavelength in meters} = \frac{300}{\text{frequency in MHz}}$$

7. Mount the antenna at or near this height. (Physical height is not too critical. Height plus or minus .1 wavelengths will function well.)

8. Tune the equipment to the operating frequency and operate.

9. Change frequencies as required by propagation. (Since any antenna height between .1 and .25 wavelengths will direct the energy in a verticle direction, raising and lowering the antenna will almost never be necessary once it is positioned.)

This information in conjunction with Appendix N of *FM 24-18* will allow the tactical communicator to engineer HF systems which will permit 24-hour-a-day operation at ranges up to 500 miles without skip zones. There are two critical elements of this approach which operators must understand. First, propagating frequency bands vary throughout the day depending on the time (sun position). In order to remain in communication, operators must adjust the frequencies, typically at sunup and sundown; however, some propagating frequency will always exist. Second, operators must properly match the antenna impedance to the transmitter in order to efficiently radiate energy. Once this is accomplished, they must select the proper antenna heights in order to direct the radiated energy at the desired angle. Due to the symmetry of high angle radiation, antenna orientation is not a factor and field strength patterns are totally omnidirectional.

The operational experience of the state area command of the New Jersey Army National Guard net shows that 31 stations operating at ranges varying from 5 to 125 miles can provide reliable communications under all conditions if the procedures outlined above are followed and the

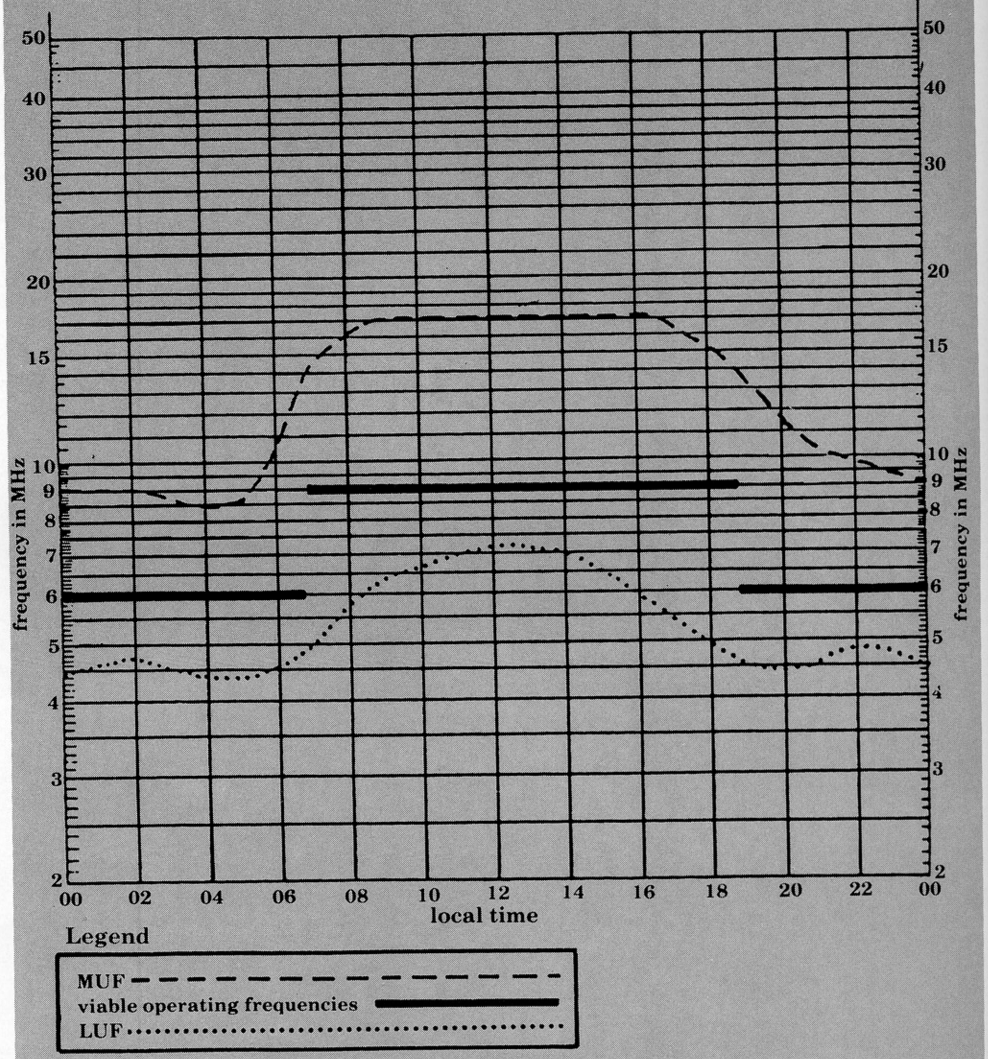

Figure 6. Typical daily variation of the maximum useable frequency (MUF) and lowest useable frequency (LUF), along with suggested operating frequencies. Note that the MUF and LUF values are lowest at night and peak around noon. Operators can maintain 24-hour communications by using a frequency safely between the MUF and LUF. In the example above, 24-hour operations can be achieved by operating near 6 MHz from 1900-0700 and near 9 MHz from 0700-1900 (necessitating only two frequency changes per day).

critical elements of antenna and frequency usage are properly considered.

In light of the above information, let me again urge the Army Signal Center and School to incorporate this information along with the information in *FM 24-18,* Appendix N into the Signal School's program of instruction and to change all Army literature to reflect this information. As we move into the late 1980s and 1990s, it is becoming more and more obvious that HF radio will be the best, if not the only, means of radio communications when beyond line of sight (BLOS) ranges are required, when satellite communications have been destroyed or disrupted, and in situations such as quick recovery after a nuclear exchange, high intensity short duration operations, or anti-terrorist operations.

Both the Air Force and the Navy have recognized these facts and consequently devote many hours of instruction to antennas, radio propagation, frequency selection, and the characteristics of skywave paths in their programs of instruction and manuals. Of particular note is Air Force *Communications Pamphlet 100-16,* which has an excellent chapter on short skywave paths. Unfortunately, in my recent conversation with graduates of the HF Radio Operators Course (31C) and the Communications Electronics Officer Course (25A) (admittedly a small sample, but I think representative), I detected a decided lack of knowledge in this area. Such a lack of knowledge cannot be tolerated if we are to utilize our enormous investment in HF communications equipment effectively and efficiently. The technology exists today. It is up to the Signal Corps (particularly the Signal Center and School) to get this information into the program of instruction and out to the troops where it will do the most good. Above all, we must banish forever the term "skip zone" and the thinking that created it.

References

1. Appendix N, **FM 24-18, Tactical Single-Channel Radio Communication Techniques,** *13 December 1984, Headquarters, Department of the Army, Washington, D.C.*

2. Air Force **Communications Pamphlet 100-16, High Frequency Radio Communications in a Tactical Environment,** *20 September 1968, Department of the Air Force Washington, D.C.*

3. **The Rules of the Antenna Game,** *1984, W5QJ4 Antenna Products, P.O. Box 334, Melbourne, Fla. 32902-0334.*

4. **ARMY COMMUNICATOR,** *Fall 1983, p. 14, "Beyond line of sight propagation modes and antennae," by David M. Fiedler and George H. Hagan, U.S. Army Signal Center and School, Fort Gordon, Ga. 30905.*

Lt. Col. Fiedler was commissioned in the Signal Corps upon graduation from the Pennsylvania Military College in 1968. He is a graduate of the Signal Officers Basic Course, the Radio and Microwave Systems Engineering Course, the Signal Officers Advanced Course, and the Command and General Staff College. He has served in Regular Army and National Guard Signal, infantry, and armor units in CONUS and Vietnam. He holds degrees in physics and engineering and an advanced degree in industrial management.

Lt. Col. Fiedler is presently employed as the chief of the Fort Monmouth Field Office of the Joint Tactical Fusion Program (JTFP) and as assistant project manager (APM) for Intelligence Digital Message Terminals (IDMT). He is also chief of the C-E Division of the NJ State Area Command (STARC), NJARNG. Prior to coming to the JTFP, Lt. Col. Fiedler served as an engineer with the Army Avionics, EW, and CSTA Laboratories, the Communications Systems Agency (CSA), the PM-MSE, and the PM-SINCGARS. The author of several articles in the fields of tactical communications and electronic warfare, he has served as a consultant to the Army Study Advisory Group (SAG) for theater communications and as a member of the Mobile Subscriber Equipment (MSE) Evaluation Board.